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November 29, 2011

SUBMITTED VIA HAND DELIVERY

Mr. Steven Way
On-Scene Coordinator
Emergency Response Program (8EPR-SA)
US EPA Region 8
1595 Wynkoop Street
Denver, CO 80202-1129

RE: Submittal of Rico-Argentine Mine Site Preliminary Water Treatment Technology Screening Report, EPA Unilateral Administrative Order, Docket No. CERCLA -08-2011-0005.

Dear Mr. Way:

In accordance with the Unilateral Administrative Order (CERCLA-08-2011-0005), Atlantic Richfield Company ("Atlantic Richfield") is submitting the attached *Preliminary Water Treatment Technology Screening Report*. The report was assembled pursuant to Subtask F1 of the *Removal Action Work Plan: Rico-Argentine Mine Site – Rico Tunnels Operable Unit OU01*.

Consistent with discussions between EPA and Atlantic Richfield this summer, and in accordance with our letter to you dated October 4, 2011, in addition to screening technologies for the assessment of water treatment alternatives for St. Louis Tunnel discharges, this report identifies additional data needed for the final analysis of possible treatment alternatives.

If you have any questions or comments, please feel free to contact me at the numbers above or via e-mail at anthony.brown@bp.com.

Sincerely,

Anthony R. Brown

Anthony Brown
Project Manager Mining

Preliminary Water Treatment Technology Screening Report

Rico-Argentine Mine Site

Prepared For: Atlantic Richfield Company

Copper Environmental
Consulting, LLC

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1.0 Purpose and Scope

This report evaluates and compares water treatment technologies that could potentially be applied to discharges from or related to the St. Louis Tunnel in accordance with Subtask F1 of the Removal Action Work Plan (RAWP) attached to the Unilateral Administrative Order (UAO), dated March 9, 2011 (Docket No. 08-2011-0005).

> "Water treatment technologies applicable to treating mine discharge water will be evaluated and compared to the proposed lime treatment system based on the efficiency of metals removal, metals recovery potential, construction and operating cost, solids disposal requirements, long-term performance and other factors necessary for comparing and selecting the technology most likely to facilitate treatment of the discharge to the satisfaction of all parties and meet regulatory obligations."

The screening evaluation looks at treatment technologies that may be used for flows exiting the St. Louis Tunnel and for flows thought to be entering the St. Louis Tunnel underground workings from upgradient source areas, including the Blaine Adit and Argentine Shaft. The upgradient source areas, the extent to which they contribute to metals loading and flows at the St. Louis Tunnel, and the technical feasibility of source control are being separately investigated under Task E of the RAWP. For purposes of this report, consideration is given to possible treatment technologies that may aid in intercepting and addressing the source area flows before they reach the St. Louis Tunnel, thereby diminishing or eliminating the need for active treatment below the St. Louis Tunnel discharge. Pending completion of the Task E investigations, however, treatment of the Blaine Adit and Argentine Shaft flows is being evaluated and considered only as a possible alternative to water treatment at the St. Louis Tunnel.

In this report, various technologies are screened based upon effectiveness, implementability, and cost criteria, consistent with EPA guidance for conducting Non-Time Critical Removal Actions (EPA, 1993). In addition to screening water treatment technologies, this report evaluates data gaps and needs related to the formulation and evaluation of site-specific water treatment alternatives. The scope and level of analysis of site-specific water treatment alternatives is necessarily limited until additional data is collected and until some of the other tasks required under the RAWP are completed, including Task E (Source Water Investigations and Controls) and Task B3 (Pond Stability Analysis).

2.0 Background Information

2.1 Location

The site is defined in the UAO as the complex of tunnels and facilities at the Rico-Argentine Mine, including a series of settling ponds located down-gradient of the St. Louis Tunnel. The Rico-Argentine Mine Site is located approximately 0.75 miles north of the Town of Rico in Dolores County, Colorado (see Figure 1: Project Location Map). The site is accessed from an existing 0.75 mile gravel road from Colorado State Highway 145 (see Figure 2: Project Vicinity Map). Highway 145 provides access from the north through Telluride and Montrose and from the south through Cortez and Durango. Telluride is approximately 27 miles away, Montrose is 86 miles away via US Highway 550 and State Highway 62, Cortez is 50 miles away, and Durango is 92 miles away via US Highway 160 and State Highway 184.

2.2 Topography

The site lies at the base of Telescope Mountain in a relatively flat area adjacent to the Dolores River (see Figure 2: Project Vicinity Map). Telescope Mountain reaches a peak elevation of 12,221 feet while the average elevation at the St. Louis Ponds is approximately 8,800 feet; maximum relief over the St. Louis Ponds is on the order of 130 feet. The original Dolores River floodplain that occupied the St. Louis Ponds has been significantly modified as a result of the historic mining and ore processing activities. At present, the active channel and floodplain of the Dolores River are confined to the western portion of the historic floodplain, and are separated from the St. Louis Ponds by a contiguous constructed dike along most of the east bank of the river.

2.3 Climate

Climate at the site is characterized as semi-arid with long, cold, snowy winters and short, moderately wet and warm summers. Monthly and annual climatic data has been compiled by the Colorado Climate Center at Colorado State University for Rico station 57017 from 1893 through 1993. The mean annual temperature is 38.7ºF. The warmest months are June, July, and August with monthly mean temperatures of about 55ºF. The coldest months are December, January, and February with monthly mean temperatures of about 6.5ºF.

Mean annual precipitation in the Rico area is about 27 inches. Most of this precipitation occurs as snowfall in the fall, winter, and early spring, averaging about 173 inches of snow per year. Average total monthly precipitation ranges between about 1.4 and 2 inches, with June being the driest month and July and August the wettest months with almost 3 inches per month on average. The driest fall month is November with about 2 inches of precipitation on average.

2.4 Site History

The history of the Rico-Argentine area includes periods of mining-related activity and associated narrow gauge railroad construction. Located in the Pioneer District, mining in the Rico area began in 1869 with the first claim being staked on lower Silver Creek. The Rio Grande Southern Railroad (RGS) arrived in Rico in 1891, connecting Ridgeway to the north and Durango to the south. The RGS provided freight and passenger service to Rico and the Pioneer District until the line was abandoned in 1951.

Significant mining activity in Telescope Mountain began in the early 1900's and flourished with the onset of the First World War at the Mountain Spring-Wellington mine. In 1930-1931, mining in the area was expanded with the driving of the St. Louis Tunnel by the St. Louis Smelting & Refining Company; a division of National Lead Company.

A major crosscut to the north was driven, connecting the St. Louis Tunnel to the still active Mountain Spring-Wellington mine. Given the geologic and groundwater conditions within Telescope Mountain, this tunnel is assumed to have become a source of mine water discharge to the Dolores River. Construction of the St. Louis Ponds system is believed to have begun about the same time as the driving of this crosscut. Another crosscut from the St. Louis Tunnel to the southeast was driven in 1955, connecting the Argentine Mine on Silver Creek. This presumably resulted in additional groundwater discharges as a large area of interconnected mine workings and faulted/fractured ground was intercepted and connected to this new crosscut.

Additional details regarding the history of the Rico-Argentine Mine Site are provided in the RAWP and the Colorado Discharge Permit System Application, Attachment 14 submitted by Atlantic Richfield to the Colorado Department of Public Health and Environment (CDPHE) on August 4th, 2010.

2.5 Acid Rock Drainage Sources

The Rico-Argentine Mine Site has three primary openings of access to the flooded underground workings of the mine: the St. Louis Tunnel, the Argentine Adit and Shaft, and the Blaine Adit (see Figure 2: Project Vicinity Map). Analyses of historical data in conjunction with recent findings have found low flow rates of acid rock drainage having high concentrations of dissolved metals in the Argentine Shaft and Blaine Adits. Some portion of these flows progress through the underground workings beneath Telescope Mountain before their eventual discharge from the St. Louis Tunnel. Identification of these sources has led to two potential treatment locations of acid rock drainage at the Rico-Argentine Mine Site. Outside of treating the entire discharge at the St. Louis Tunnel, it has been hypothesized that treatment of a lower flow, higher concentration source water at the Blaine Adit or Argentine Shaft could potentiaiiy improve water quality at the St. Louis Tunnel discharge to the point that a water treatment system at the St. Louis Tunnel would be unnecessary.

2.6 Facilities/Features

The St. Louis Tunnel portal is located at the base of Telescope Mountain in the north-central portion of the site. A roofed cinder block structure is still present at what is believed to be the original portal location. Approximately 200 feet of the tunnel behind the portal structure has collapsed due to uncontrolled grading on the slope above the adit.

A soil-lead repository occupies approximately 2.6 acres at the base of Telescope Mountain in the north-central portion of the St. Louis Ponds site. This repository accepts soils with elevated lead concentrations removed from the Town of Rico, currently under the Rico Town Site Soils Voluntary Clean-Up Plan. The repository has a capacity at full build-out of 40,000 cubic yards. Approximately 8,000 cubic yards of soil have been disposed of at the repository to date.

The abandoned metal building and adjacent steel silo of the original lime addition plant are present near the portal of the St. Louis Tunnel. All lime handling, mixing, and feed equipment has been removed from the building and silo.

2.6.1 The Existing Pond System

A series of constructed ponds occupies most of the central and southern portions of the St. Louis Ponds area. Some of these ponds were originally constructed to receive calcines from on-site sulfuric acid production. Other ponds may have been constructed for eventual use as tailings disposal cells or to settle sediment that was present in the discharges from the St. Louis Tunnel, especially during periods of active mining and underground ore haulage.

Embankments of the upper ponds along the Dolores River have been raised and armored with riprap to provide protection against a flood. Based on available data from subsurface exploration and associated laboratory testing, it appears that the existing embankments were constructed from earthen materials available on site. Activities are currently underway to characterize the stability of the pond embankments as described in subtask B3 of the RAWP.

2.7 Utilities

The only active utilities at the St. Louis Ponds are electric power and telephone lines. Both services are via overhead wires on shared wooden poles. The electrical service provider is San Miguel Power Authority and telephone service is provided by Farmers Telephone Company. There is cellular phone coverage at the site.

2.8 Preliminary Design Parameters

Influent Water Quality and Flow Rate

For the purpose of screening water treatment technologies within this Preliminary Report, historical data was used to quantify concentrations of potential constituents of concern (COCs) at the St. Louis Tunnel discharge, the Blaine Adit, and the Argentine Shaft. Average, minimum, and maximum values of contaminants of concern for the available water quality data are presented in Table 1: **Influent Water**

Quality and Flow Rate. The earliest recorded data of the St. Louis Tunnel discharge dates back to 1973, providing a large sampling size for constituent and flow characterization. Recorded data for the Blaine Adit dates back to 1977 but is very infrequent, contains very little water quality data, and contains significant uncertainty related to the quality of the data. Water quality for the Argentine Adit includes only one sampling event, and no flow data is available.

Discharge Water Quality

For the purpose of screening water treatment technologies within this Report, the preliminary effluent limits are assumed to be those defined by the 2008 CDPHE Water Quality Assessment of the St. Louis Tunnel Discharge into the Dolores River (WQA) and are taken directly from that Assessment. The WQA provides discharge criteria for Water Quality Based Effluent Limits (WQBEL), Anti-Degradation Based Average Concentration (ADBAC) limits, and Non-Impact Limits (NIL). A summary of the discharge criteria for the contaminants of concern are presented in Table 2: Preliminary Discharge Limits.

3.0 Water Treatment Technology Screening

3.1 Screening Criteria

To identify applicable treatment technologies for further evaluation at the Rico-Argentine Mine Site, a table was developed that identified many of the potentially applicable water treatment technologies. The table was then used to screen the various technologies against known site conditions; thus allowing for the identification of inappropriate technologies that would no longer be considered (see Table 3: Water Treatment Technology Screening). Technologies to be further evaluated within site-specific treatment alternatives were given a status of "Retained." The screening of technologies was based upon the three major criteria presented in the EPA document: *Guidance on Conducting Non-Time-Critical Removal Actions Under CERCLA* (EPA, 1993). The criteria are located in the header row across the top of the table: Effectiveness, Implementability, and Cost.

Effectiveness

The effectiveness criterion is used in screening treatment technologies for the purpose of identifying those which are unlikely to ensure protectiveness or achieve established removal goals. Protectiveness is defined as a technology's ability to provide conditions protective to the public and community, workers during implementation, and the environment. Technologies considered for the Rico-Argentine Mine Site are screened on two effectiveness sub-criteria: removal efficiency/immobilization and capability to meet aquatic & human health standards.

Implementability

Implementability is used in screening treatment technologies to determine their practicality of application. This category identifies technology characteristics, either technical or administrative, that are impractical for implementation at the specific site. Criteria used in screening implementability are as follows: the state of technical development, the residuals/emissions generated, and managerial considerations.

Cost

Cost is used within the table to allow for the screening of technologies by comparing estimated initial and continuing costs. Criteria used in screening cost are capital costs, operation and maintenance costs, and resource recovery potential.

3.2 Technology Considered

Technologies considered for application to the Rico-Argentine Mine Site are divided into three categories located at the left side of the screening table: Biological Treatment, Chemical Treatment, and Physical Treatment (see Table 3: Water Treatment Technology Screening).

Biological Treatment

Biological processes alter the chemical composition or oxidation state of inorganic compounds to more stable, less mobile, and/or less toxic forms. Biological treatment process options considered for treatment of the Rico-Argentine Mine Site discharge include microbial mats, sulfide reducing bioreactors, and constructed wetlands.

Chemical Treatment

Synthesis, decomposition, or replacement reactions are used to remove contaminants from an aqueous flow stream in chemical treatment. Chemical treatment process options considered for treatment of the Rico-Argentine Mine Site discharge include Anoxic Limestone Drains, Electrocoagulation, Ion Exchange, Lime Treatment-Lagoon Settling, Lime Treatment-Conventional Plant, Lime Treatment-High Density Sludge Plant, and Sulfide Precipitation.

Physical Treatment

Physical processes remove contaminants through filtration or sequestration processes. Physical treatment process options considered for treatment of the Rico-Argentine Mine Site discharge include Electrodialysis, Evaporation Ponds, and Reverse Osmosis.

3.3 Biological Treatment

3.3.1 Microbial Mats

Technology Description

Microbial Mats use the activity of aerobic and anaerobic bacteria to remove metals from mining impacted water. Composed of stacked layers of ensilaged grass and grown and harvested like a crop, a microbial mat has a consortium of bacteria that sorb and sequester dissolved metals using ion exchange, reduction, oxidation, and bio-flocculating mechanisms.

Microbial mats have a rapid growth rate and are able to survive harsh environmental conditions such as high salinity and low pH. Composed primarily of cyanobacteria, microbial mats are photosynthetic and require atmospheric carbon dioxide. They also tolerate high concentrations of toxic compounds that will kill plants or algae.

This technology is a low cost, semi-passive alternative that may be used for temporary or permanent treatment applications. Being photosynthetic, these systems are solar driven and require less power to implement than other technologies. Although this technology thrives in hot climates, it is sustainable in cold temperatures. Exhausted mats can be dried to 1-2% of their wet volume and will not produce as much waste as precipitation, adsorption, or ion exchange processes. This process may allow recoverable metal capability.

Although capable of removing contaminants by physical filtration, mat performance is hindered by solids accumulation. This technology will require a pretreatment process if suspended solids are present in the waste stream. Microbial mats have not been found to be an effective means of treatment under pH conditions less than 2, or high concentrations of iron, manganese, and aluminum.

Technology Effectiveness, Implementability, & Cost

Microbial mat technology is easily impiementable and can be extremely effective in removing dissolved metals under optimum conditions. Although the state of technical development of microbial mat technology is innovative, capital and O&M costs of microbial mats can be low in relation to many active treatment processes.

Technology Retention Status

The presence of iron and aluminum in discharges, cold winter climates, geographic location, and flow magnitudes all pose questions as to the ability of the microbial mats to meet discharge standards. Iron and aluminum contaminants can prematurely precipitate out of solution, leading to the fouling and clogging of mats. Cold winter climates and the amount of sunlight at the bottom of a valley may also hinder microbial mat activity. This technology is not retained for consideration as an alternative given these reasons and due to its likely inability to meet discharge requirements under relatively high flow conditions.

3.3.2 Sulfate Reducing Bioreactors (SRBs)

Technology Description

Anaerobic bioreactor technology removes dissolved metals from waste streams through sulfide precipitation. The microbial process of sulfate reduction produces aqueous hydrogen sulfide and bicarbonate within a reactor. The hydrogen sulfide anion, along with some hydrogen sulfide gas, is produced in the reactor allowing for the precipitation of contaminants as metal sulfides. Bicarbonate created within the reactor promotes an increase in pH and the additional removal of contaminants as metal carbonates. Dissolved metals such as cadmium, copper, nickel, lead, and zinc are removed in the process at pH values above 5 to 7. Other metals and metalloids such as arsenic, chromium, selenium, and uranium are removed as precipitates as a consequence of a change in reduction-oxidation potential of influent streams.

SRB technology may be utilized in the form of active or passive treatment systems. Typical active systems mimic conventional gravity separation facilities in that they consist of a bioreactor (chemical addition system), a flash tank, and a clarification unit. Active systems can accommodate high flow rates and regulate retention times, chemical addition, and flow control. Typical passive systems consist of a series of settling ponds with adjoining reactor cells. Treated water is flushed through the bioreactors and mixed with influent contaminant streams to promote sulfide precipitation. Both active and passive facilities may require systems controlling pH of influent waste streams and the addition of a carbon source for microbial sustainability.

Generated wastes from sulfide precipitation have lower sludge volumes than those generated in hydroxide precipitation and possess characteristics ideal for metal recovery. Sale of generated wastes can sometimes offset some of the cost of treatment.

Technology Effectiveness, Implementability, & Cost

Actively managed SRBs can be expensive to implement and maintain; however, they are effective at removing contaminants (though they do not always meet aquatic and human health water quality standards). These facilities require special attention to human safety and plant maintenance, as hydrogen sulfide gas is continuously produced. Hydrogen sulfide gas is highly toxic, corrosive, and flammable.

Passive SRBs have lower capital and O&M costs than their active counterparts. They require large footprints, but can be constructed in remote areas. Although passive SRBs can be effective at metals removal, they are unreliable in meeting discharge requirements with variable flow rates. SRBs typically allow for very little control over the treatment process.

Technology Retention Status

SRB technology is not retained for treatment alternative consideration. Passive and active SRBs have low effectiveness in meeting discharge requirements under high flow conditions. In comparison to conventional lime addition treatment facilities, active SRBs have similarly high O&M costs and pose health and maintenance risks with the production of hydrogen sulfide gas byproducts.

3.3.3 Constructed Wetland

Technology Description

Constructed wetlands provide treatment under aerobic and anaerobic conditions through a series of chemical, biological, and physical processes: photosynthesis, respiration, settling & filtering, and oxidation/reduction reactions.

Photosynthesis contributes to water treatment by using light energy and CO_2 to form organic matter and O_2. This process reduces the partial pressure of CO_2 within the waste stream, shifting the water chemistry to a higher pH and precipitating dissolved metals as hydroxides. Created organic matter from photosynthesis allows for other treatment processes to occur within the system through respiration and metabolism. A large benefit of the production of organic matter, especially by algae, allows for other zones of the system to become anaerobic. The production of O_2 increases the oxidation potential, most notably at the micro-environment sites. Photosynthesis is dependent on many factors, some of which are light intensity (depth of penetration in water column), duration of light, temperature, nutrient availability, pH, Eh, and cation/anion concentrations.

Aerobic respiration produces energy for cell use by the consumption of organic matter and oxygen. This process produces organic matter with lower molecular weight and increases the concentration of CO_2, decreasing pH. The main benefit of aerobic respiration is the consumption of oxygen, turning conditions anaerobic. Deeper portions of a constructed wetland can have decreased oxygen concentrations due to aerobic respiration. The decrease of oxygen allows organisms to exist which use other electron acceptors for anaerobic respiration.

Anaerobic respiration involves the formation of energy for cell use by the consumption of organic matter and electron acceptors other than O_2. The electron acceptors can be ferric iron, sulfate, nitrate, and CO_2. Anaerobic respiration produces changes in organic matter chemistry and evolves alkalinity and CO_2. The change in organic chemistry creates lower molecular weight organic compounds. The electron acceptors are reduced (e.g. sulfate to sulfide). Anaerobic respiration is anticipated to be active near the pond bottom, in sediments below the pond, and within the interior of permeable treatment walls. The main treatment benefits are the reduction of sulfate and nitrate and attenuation of metals and metalloids via the formation of sulfide complexes. The establishment of an anaerobic zone at the pond bottom and in the interior of the treatment walls is hypothesized to be beneficial in the reduction of metal concentrations in the water and in the stability of the formed solids.

Settling and filtering removes suspended solids from retained water. Decreased water velocity allows settling of particles which were suspended due to the motion of water. Filtering of solids occurs due to particle collection as the water passes through a medium which traps particles due to size relationships of suspended particle size to pore throat size. It is anticipated that solids that are settled and filtered out will reside in anaerobic zones or in the transitional zones between aerobic and anaerobic. The chemistry of those zones will be dependent upon all of the interactions of the above processes.

Most of the treatment processes of constructed wetlands have impacts on both the pH and redox potential throughout the system. Certain processes will be predominant in one portion of the system and have negligible impact in other portions of the system. The establishment of these significantly different environments is anticipated to be critical for reduction of certain metals and non-metals dissolved in the water and the formation of chemically insoluble and stable solids. Zones higher in oxidation potential and neutral-basic pH will be near the surface of the open water cells. The high oxidation potential is due to diffusion of oxygen from the atmosphere to the water and production of molecular oxygen via photosynthesis during daylight. Formation of metal oxyhydroxides will reduce the concentrations of ions in the water and form solids, which will settle in the open water system. Dead organisms from the water column and detritus material from surrounding plants will also settle to the bottom.

Depending on the water chemistry, the solid composition will be either carbonates and oxyhydroxides or carbonates and sulfides. Similar to wet closure treatment, wetland treatment lagoons may limit oxidation, potential mobilization of contaminants, and provide a sediment control function by acting as a barrier to downstream movement of solid material.

Technology Effectiveness, Implementability, & Cost

Constructed wetlands are an effective means of metals removal from acid rock drainages; but, have been unreliable in consistently meeting discharge requirements under variable flow rates. It could be argued that the current St. Louis Pond system is essentially an open water (primarily aerobic) constructed wetland treatment system. Water quality data has indicated that the pond system alone cannot meet anticipated water quality standards. Implementation of enhancements to the constructed wetlands at the Rico-Argentine Mine Site may be feasible. Capital and O&M costs may be relatively low in comparison to active treatment processes.

Technology Retention Status

Constructed wetland technology is retained for further consideration. Although ineffective at meeting discharge requirements under variable flow conditions, the low capital and O&M costs associated with implementing this technology at the Rico-Argentine Mine Site may make this technology a feasible solution if used in conjunction with another technology.

3.4 Chemical Treatment

3.4.1 Anoxic Limestone Drain (ALD)

Technology Description

ALDs are passive treatment systems used to treat acid rock drainage. Placed in anaerobic conditions, these systems consist of a buried bed of limestone used to intercept mine discharge and add alkalinity through its own dissolution. ALDs can treat large variances of flows and their design is dependent on dissolved metal concentrations and retention times required to raise pH. An ALD is lined with an impervious barrier and filled with limestone. The sealed limestone trench is then covered with clay or compacted soil to maintain anoxic conditions within the system.

Ensuring anaerobic conditions within the ALD is crucial to the system's effectiveness and longevity. Anoxic conditions may prevent certain metals from precipitating out of acidic rock drainage within the drain. With the formation of these precipitates comes adverse armoring of limestone and clogging of pore spaces. Contaminant removal occurs downstream of the anoxic limestone drain under aerobic conditions. Anoxic limestone drains may be used for temporary or permanent solutions; however these systems have reduced effectiveness over time and eventually require replacement with continual dissolution.

Technology Effectiveness, Implementability, & Cost

The primary attraction to using ALD treatment systems is low capital and O&M costs. Effectiveness of ALDs in removing dissolved metals is variable because control of lime addition to fluctuating conditions of influent chemistry is difficult to control. When used autonomously for treating acid rock drainage, ALDs have been largely unreliable in meeting discharge requirements.

Implementation of an ALD system at the St. Louis Tunnel is likely to be difficult. Common practice for installation of an ALD at a mine tunnel is to plug the adit. This procedure creates anoxic conditions before the drain, preventing armoring and clogging of the system; however, it can create many other issues related to backing up water in the mine workings.

Technology Retention Status

ALD technology is not retained for consideration in treatment alternatives due to low effectiveness in meeting discharge requirements coupled with unpredictable levels of treatment.

3.4.2 Electrocoagulation (EC)

Technology Description

EC systems remove dissolved contaminants from influent waste streams through the administration of an electrical current. EC removes metals, colloidal solids and particles, and soluble inorganic pollutants through the introduction of electrically produced ions or highly charged polymeric metal hydroxides. In addition, this process removes suspended solids and oils by neutralizing their electrostatic charges, causing them to agglomerate.

In the EC treatment process, waste water passes through an electrolytic cell containing anodic and cathodic reactor plates. When supplied with an electrical current, these electrodes continuously produce ions into the waste stream that neutralize the charges of dissolved particles, initiating the coagulation process. Colloidal particulates or other contaminants are physically and/or chemically altered under the applied electric field through ionization, electrolysis, hydrolysis, and free-radical formation. These processes cause contaminants to be precipitated or destroyed.

Characteristics of generated solids from the EC process differ greatly from those produced in more conventional chemical precipitation processes. Electrocoagulated solids have lower volumes, contain less bound water, and are more readily filterable. EC is a more favorable technology for treatment where reuse of water is necessary. The EC process yields discharge effluents with lower total dissolved solids than conventional chemical precipitation processes.

Technology Effectiveness, Implementability, & Cost

Although EC has had success in the mining industry with meeting discharge requirements of dissolved metals, the technology is still in an innovative phase. Most information gathered on the EC process is either site or contaminant specific. This technology is relatively impiementable since it requires standard equipment and is relatively easy to operate. Capital costs for an EC facility are high. O&M costs are anticipated to be higher than a chemical precipitation facility with similar design criteria.

Technology Retention Status

EC technology is not retained for treatment alternative consideration. There is significant uncertainty regarding this technology's ability to treat larger and variable flow rates at competitive O&M costs. Although EC technology is being applied in certain industrial settings, it is still a relatively unproven technology.

3.4.3 Ion Exchange (IE)

Technology Description

Ion exchange treatment systems remove dissolved contaminants from an aqueous stream by exchanging them with ions on a solid, insoluble substrate. Substrates used in IE are most commonly resins that have fixed charged functional groups located on their external and internal microporous surfaces. Resins are designed for the removal of either cations or anions from solution. There are four general types of exchange resins: strong acid cation, weak-acid cation, strong-base anion, weak-base anion. These resins have different electrochemical potentials for exchanging ions under different conditions.

Chemical properties of dissolved ions, such as valence magnitude and atomic number, affect their uptake by IE resins. Ion uptake is also dependent upon physical properties of the resin, such as pore size distribution and type of functional groups. These properties determine the selectivity or rate at which ions are exchanged from the aqueous stream.

Prior to treatment, the functional groups of a resin have electrostatic interactions with low affinity counterions (e.g. H^+, Na^+, OH^-, or Cl^-). Exchange of ions is driven by differences in the electrochemical affinities of dissolved contaminants and affixed counterions. When placed in a waste stream, dissolved contaminants are exchanged with the low affinity counterions, separating them from solution. Established electrochemical gradients, otherwise known as the Donnan potential, drive the exchange of ions from the aqueous to the resin phase.

Pretreatment of the waste stream is generally required in the use of ion exchange for the removal of suspended solids and pH control for optimum metals removal specific to the resin. Over time IE resins become saturated with waste ions and require a regeneration process. Because of the regeneration process, typical systems employ redundant lag and lead IE columns. The lead column is taken off-line and backwashed with a pH controlled solution for the release of exchanged contaminants into solution. This solution is captured for disposal or metal recovery. The column is then flushed with an additional solution for replacement of counterions to the functional groups of the resin. Upon completion of the regeneration process, the column is placed back on-line in the lag position.

Technology Effectiveness, Implementability, & Cost

IE can be an effective method of metals removal from waste streams; however, full-scale demonstrations of IE technology as a stand-alone treatment alternative for acid rock drainage are rare. This technology is not an effective means of treatment for waste streams containing suspended solids, high concentrations of iron, or high concentrations of aluminum. Implementation of this technology is simple in that most systems are portable and provide immediate results. Capital and O&M costs of IE are moderate to high.

Technology Retention Status

IE technology is retained for consideration in treatment alternatives. Although waste streams at the Rico-Argentine Mine Site have aluminum and iron constituents, IE technology may be utilized in conjunction with other retained technologies while providing a potential for resource recovery.

3.4.4 Lime Treatment – Lagoon Settling

Technology Description

The treatment of acid rock drainage through lime addition removes dissolved metals by chemical and physical processes. Metal solubility is dependent, in part, upon pH. Lowering the pH of an aqueous stream correlates to an increased solubility of metals. Conversely, increasing the pH of acid rock drainage through lime addition reduces the solubility of many dissolved metals which precipitate out of solution primarily as metal hydroxides. In this instance, the solid particles are then physically removed from aqueous matter by gravity separation in open-water lagoon ponds.

Optimum precipitation of various dissolved metals occurs at different pH values. In meeting discharge standards for nickel, manganese, silver, and cadmium, a pH greater than 9.5 may be required. Adjusting pH to this higher level can sometimes cause other metals having lower optimum precipitation points to re-solubilize. Other metals (such as chromium and selenium) require reduced valences before hydroxide precipitation can be accomplished.

Following chemical treatment by lime addition, precipitates are separated from aqueous matter through gravity settling in a lagoon pond system. Designed for minimum retention times and laminar conditions, lagoon systems allow for the separation of solids under high and variable flow rates. Lagoon systems have limited control of flow conditions and the settling of solids can sometimes be disrupted by wind. Without sludge recycle capabilities, a lime treatment – lagoon settling system can exhibit lower lime efficiency than a high-density sludge lime treatment facility.

Technology Effectiveness, Implementability, & Cost

Lime addition is a simple, proven technology for removing metals and meeting effluent standards. Used in conjunction with a lagoon settling system, it has a high effectiveness in meeting discharge requirements. Implementability of this technology is ranked high, given the presence of the existing pond system located adjacent to the St. Louis Tunnel, which could easily be upgraded for continued use as a lagoon settling system. Capital costs of upgrading this system are anticipated to be low with moderate, continued O&M costs.

Technology Retention Status

This technology is retained for consideration in treatment alternatives due to its long-term effectiveness and consistent performance in meeting water quality discharge requirements.

3.4.5 Lime Treatment – Conventional Plant

Technology Description

A conventional lime treatment facility for acid rock drainage typically consists of an equalization pond, a reactor, and a clarifier unit. Sludge is not recycled to the reactor, as would be the case for a "high-density sludge" system (see next Section). Acid rock drainage discharges are first collected in an equalization pond to minimize variable flow rates. The water then enters a lime reactor where lime is added until a desired pH set point is attained. The neutralized water then enters a clarifier for separation of precipitated solids. Solids settie at the bottom of the clarifier as sludge while the treated water is collected in an overflow weir.

Additional systems may be implemented on a conventional treatment train for improved water treatment. An aeration system could be installed within the reactor to assist in the precipitation and co-precipitation of iron, manganese, and arsenic. For discharges containing high concentrations of dissolved carbon dioxide, aeration of the waste stream will help raise pH, minimizing lime dosing. A flocculent addition system could be installed prior to the clarification process. This system continuously injects a polymer into neutralized AMD to generate larger flocculent size, increasing the density of precipitated solids and decreasing the time required for separation of solids. A final treatment system could be installed to treat the collected overflow from the clarifier. This process would be a polishing step to further reduce residual suspended solids before discharge.

Technology Effectiveness, Implementability, & Cost

Conventional lime treatment plants are a proven method for metals removal and meeting discharge requirements. Due to their popularity, they are easily implemented and have moderate to high capital and O&M costs. These facilities have greater lime efficiency and increased control in treating acid rock drainage. A disadvantage of this technology is the large volume of sludge that it generates. Sludge generated from this process can be less than 5% solids, which can result in substantial solids management costs.

Technology Retention Status

This technology is not retained for consideration in treatment alternatives. Although this technology has high effectiveness and is easily impiementable, the improved sludge management and reduced O&M cost offered by the High Density Sludge process (see below) removes this technology from further consideration.

3.4.6 Lime Treatment – High Density Sludge Plant

Technology Description

High Density Sludge (HDS) treatment systems are widely used due to their increased lime efficiency and lower volumes of generated sludge in comparison to the conventional lime treatment system described above. Similar to a conventional lime treatment system, a high density sludge system has one additional process: sludge collected at the bottom of the clarifier is pumped to an alkalization tank where it is mixed with lime. The created lime/sludge slurry then becomes the neutralizing agent used in the reactor tank.

By coating sludge particles with the alkaline properties of the lime, precipitation of dissolved metals occurs on the surface of preexisting precipitates. The result is the formation of much larger and denser sludge particles which have lower volumes and faster settling characteristics. Lime efficiency is further increased in an HDS process. By using sludge that has alkaline properties from previous neutralization, less lime is required in controlling the influent water pH. Additional systems for aeration, flocculation, and polishing may be added to a HDS treatment train to improve discharge quality.

As with any type of lime treatment system, treating acid rock drainage having high sulfate concentrations can cause the formation of gypsum scale in pipes and equipment. Supersaturation and the eventual precipitation of gypsum creates a very hard scale build-up on pumps, pipes, and surface walls of facility equipment which is very difficult to remove. Scaling can lead to decreases in system hydraulic capacity and treatment efficiency while increasing O&M cost.

Technology Effectiveness, implementability, & Cost

HDS plants are highly effective at metals removal and meeting discharge requirements. This technology is very impiementable with moderate to high capital and O&M costs.

Technology Retention Status

This technology is retained for consideration in treatment alternatives due to its long-term effectiveness and consistent performance in meeting water quality discharge requirements.

3.4.7 Chemical Sulfide Precipitation

Technology Description

Chemical sulfide precipitation removes dissolved metals from aqueous flows through the addition of sulfide based reagents. Sulfide can be administered to waste streams through soluble reagents (sodium sulfide or sodium hydrosulfide) or insoluble reagents (ferrous sulfide or calcium sulfide). Sulfides are introduced to a waste stream in a reactor tank, causing dissolved metals to precipitate out of solution as metal sulfides. Flows from the reactor enter a clarifier for the separation of contaminants. The discharge of unused sulfides can lead to hydrogen sulfide gas emissions; therefore, a final treatment step of aeration or hydrogen peroxide addition is included for the oxidation of excess sulfide ions.

Sulfide precipitation has several potential advantages over more conventional lime addition precipitation processes. First, metal sulfides have a lower solubility than metal hydroxides and removal is directly related to sulfide ion concentrations. Second, sulfide precipitation may not require pH adjustment and can effectively remove metals from a wide range of influent pH conditions. Third, certain metal sulfide sludges may exhibit lower final sludge volumes, since their theoretical particle density is greater than that of most metal hydroxide particles. Last, metal sulfides may have potential for metals recovery.

Close monitoring of the sulfide precipitation process is required to prevent potential releases of hydrogen sulfide gas, which is extremely toxic and corrosive. In addition to hydrogen sulfide exposure, sulfide reagents used in the precipitation process are corrosive and pose health risks to plant operators. Another disadvantage of this technology is the potential for sludge separation difficulties. Metal sulfides tend to precipitate relatively quickly, forming particulates that are small in size. Although the solids may be more easily dewatered, they also may require longer retention times for settlement.

Technology Effectiveness, Implementability, & Cost

Sulfide precipitation has been shown to be an effective treatment technology for removing dissolved contaminants and meeting discharge requirements for metal-bearing waste streams in certain instances. Implementability of a sulfide precipitation plant is more difficult considering the additional management and safety measures required with hydrogen sulfide gas generation. This process typically has higher capital and O&M costs than a lime addition precipitation process.

Technology Retention Status

This technology is not retained for consideration as a treatment alternative. In comparison with more traditional lime addition precipitation processes, sulfide precipitation has higher costs and greater risks associated with the production of hydrogen sulfide gas.

3.5 Physical Treatment

3.5.1 Electrodialysis (ED)

Technology Description

Electrodialysis uses a series of hybrid membranes in conjunction with an applied electrical potential to separate dissolved ionic constituents from an aqueous stream. Waste streams are placed between compartments of cationic and anionic ion exchange membranes. Under an applied electrical current, negatively charged anions migrate toward the positively charge cathode and positively charged ions migrate toward the negatively charged anode. Positively charged ions pass through negatively charged cationic membranes but their movement is inhibited when encountering positively charged anionic membranes. This behavior is vice-versa for negatively charged ions.

The resulting migration of ions past the exchange membranes isolates dissolved contaminants from the flow stream in to a brine. This concentrated waste volume is approximately 15 to 25 percent of the total treated volume. Given the propensity of these waters to precipitate solids, the more conservative percentage of 25% is likely.

Only an equal number of anion and cation charge equivalents are transferred from the flow stream past the membranes, maintaining the charge balance. The applied electrical current of an electrodialysis system is measured to maintain a high efficiency, and minimize costs. The current efficiency is a function of feed concentration and can be used as a gauge for how effective ions are being transported across the ion exchange membranes. Undesirable electrical efficiencies can be identified by the back-diffusion of ions from the concentrate, short circuiting between the electrodes, or the splitting of water into hydrogen and hydroxide ions within the concentrate.

Pretreatment of the waste stream is generally required in the use of electrodialysis to remove species that coat, precipitate onto, or "foul" the surface of the stacks or membranes. High calcium and magnesium water hardness, suspended solids, silica, and organic compounds can pose potential problems for ED membranes.

Technology Effectiveness, Implementability, & Cost

Electrodialysis is effective in metals removal and meeting discharge requirements for waste flows having TDS feed concentrations less than 3000 ppm. It has high capital and O&M costs. This technology works best at removing low molecular weight ionic components.

Technology Retention Status

This technology is not retained for consideration in treatment alternatives. It has high costs and limited data for long-term effectiveness and performance in meeting water quality discharge requirements.

3.5.2 Evaporation Ponds

Technology Description

Evaporation ponds consist of surface water ponds used to concentrate contaminants by allowing aqueous media to evaporate from the system. The evaporation mechanism results in sediments deposited on the bottom of ponds. In general, evaporation rates are a function of local climatic conditions and the surface area of the pond.

Effectiveness, Implementability, & Cost

Given the flow rate of water requiring treatment and the high elevation and precipitation specific to the climate of the Rico-Argentine Mine Site, evaporation ponds are not an effective means of metals removal from acid rock drainage in this instance. They are easily implemented and have low capital and O&M costs.

Technology Retention Status

This technology is not retained for consideration in treatment alternatives. This technology is ineffective at removing contaminants from flow rates specific to the Rico-Argentine Mine Site.

3.5.3 Reverse Osmosis

Technology Description

Reverse osmosis is a membrane separation technology that uses a single semi-permeable membrane and a high-pressure gradient to remove dissolved solids from an aqueous stream. The pore size in the membrane is such that water passes through more readily than the dissolved metals. Influent water is pumped under high pressure to membrane-holding cartridges. Water with low metal levels passes through the membrane and an aqueous solution containing concentrated inorganic contaminants remains on the pressurized side of the membrane. The concentrated reject stream must be collected and managed. The relative proportions of permeate and concentrate depends on solute properties, membrane properties, flow rates, operating pressures, and the configurations and number of units used in the process.

Technology Effectiveness, Implementability, & Cost

This technology is effective in metals removal and can typically meet water quality discharge requirements. It is a proven technology, but may not be easily impiementable at the anticipated and variable flow rate. RO has very high capital and O&M costs.

Technology Retention Status

This technology is not retained for consideration in treatment alternatives. The energy needed to operate a high-pressure system and the need for permeate treatment make this a less viable and more costly process than other effective technologies. This technology is not more effective than other, less expensive technologies.

4.0 Retained Technologies

Based upon available information for the Rico-Argentine Mine Site, combined with the background information for the various technologies and professional experience, four of the original thirteen technologies have been retained for further evaluation as treatment alternatives. Table 3: Water Treatment Technology Screening provides the results of the technology screening. The following technologies ranked highest in terms of the identified screening criteria and therefore have been retained for future consideration:

1. Lime Treatment – Lagoon Settling
2. Lime Treatment – High Density Sludge
3. Constructed Wetland
4. Ion Exchange

These retained technologies will be subjected to further evaluation as part of a future Water Treatment Alternative Screening Evaluation. As part of this evaluation, site-specific conceptual design assumptions will be developed and used to estimate alternative costs and conduct detailed alternative screening against specified screening criteria. In order to develop the conceptual design assumptions for the various site-specific alternatives and in order to properly evaluate the alternatives against screening criteria; additional site and technology data is required. A data gap evaluation is presented in the following section to identify the data needs.

5.0 Data Gap Evaluation

As the various treatment technologies were screened against the specific criteria in Table 3: Water Treatment Technology Screening, it became immediately apparent that additional data would be necessary to develop site-specific alternatives based upon the retained technologies. Such additional data will allow for a systematic and objective evaluation of the site-specific treatment alternatives. In order to properly identify the data gaps, the applicability of each treatment technology to the two potential source waters (St. Louis Tunnel Area or Blaine/Argentine Area) is briefly described. Following the Description of Treatment Technology Applicability, the existing data gaps are identified that will need to be addressed to complete a systematic evaluation and thorough screening of site-specific treatment alternatives (see Section 5.2).

As noted above, this analysis assumes that treatment alternatives will be implemented at either the St. Louis Tunnel Area or the Blaine/Argentine Area, but not at both areas. The implementability and cost considerations for separate treatment systems in two different locations would render such an alternative infeasible. As described in Section 5.2, in order to properly evaluate treatment technologies in relation to the two potential treatment locations, sufficient flow and water quality data for the potential source waters is needed.

5.1 Description of Treatment Technology Applicability

The following subsections describe the applicability of each of the four treatment technologies identified as "retained for further evaluation" (see Section 4.0). Assessment of the applicability of each retained treatment technology to each of the potential treatment system areas (the St. Louis Tunnel Area and the Blaine/Argentine area) is not intended as a means to screen site-specific treatment alternatives; it is intended only to assist with the identification and prioritization of data gaps for each area. This is critical in understanding the data gaps for each technology for each potential area of application.

Applicability of Lime Addition – Lagoon Settling Technology

Though this technology is likely to be capable of treating source waters from either the St. Louis Tunnel Area or the Blaine/Argentine Area, it is anticipated that this technology would only be implemented at the St. Louis Tunnel Area due to the areal constraints of the Silver Creek valley near the Blaine/Argentine Area, and the need to construct new ponds. Successful implementation of this technology would likely include the construction of a new lime addition system at the St. Louis Tunnel Area and the use of the existing pond structures to provide settling of precipitates.

Applicability of Lime Addition – HDS Plant Technology

The Lime Addition – HDS Plant technology is likely capable of treating source water from either the St. Louis Tunnel Area or the Blaine/Argentine Area. Though future development of site-specific treatment alternatives may consider implementation of this technology in either area, it is likely that this technology would be implemented near the St. Louis Tunnel area given the areal constraints of the Silver Creek valley area. Use of the HDS Plant technology will likely require significant area for influent flow equalization and for effluent clarification. If this technology is applied to Blaine/Argentine Area source waters, it is assumed that the water would be captured/collected and routed to an HDS Treatment Plant in the St. Louis Tunnel area. Though not typically required for HDS Plant technology, the existing pond structures may be employed as a polishing treatment process before discharge into the Dolores River.

Applicability of Constructed Wetland Technology

Though additional data would be required to evaluate the concept, the use of constructed wetland technology in combination with another treatment technology may result in the successful treatment of water at the St. Louis Tunnel area if the treatment of a low flow, high concentration discharge at the Blaine/Argentine Area results in significantly improved water quality conditions at the St. Louis Tunnel. The existing pond structures in the St. Louis Tunnel area could be improved, if deemed necessary, to accommodate constructed wetland technology. Constructed wetland technology is not anticipated to fit within the areal constraints of the Blaine/Argentine area.

Applicability of Ion Exchange Technology

Ion Exchange Technology may potentially be applicable to source waters at either the St. Louis Tunnel area or the Blaine/Argentine area. As stated in the following data gap evaluation section, the development of a site-specific treatment alternative that incorporates ion exchange technology will be dependent upon filling data gaps associated with this technology's effectiveness in treating conditions specific to each source area.

5.2 Evaluation of Data Gaps and Identification of Data Needs

This section provides an evaluation of data gaps for the four retained treatment technologies identified in Table 3: Water Treatment Technology Screening. The data gap evaluation is conducted by qualitatively evaluating the following categories of design variables in relation to the four retained treatment technologies:

- Influent Flow Rate
- Influent Water Chemistry
- Discharge Standards
- Performance/Effectiveness
- Existing Pond Integrity
- Solids Management

In addition, the data gap evaluation is further refined by categorizing the data gaps based upon the two potential source waters (St. Louis Tunnel Area and Blaine/Argentine Area). Table 4: Water Treatment Technology Screening Data Gap Evaluation illustrates the results.

The data needs are identified in Table 5: Water Treatment Technology Screening Data Needs Identification. Please note that only the general data needs are identified in the table. Specific details of the data needed to fill certain gaps will require identification as part of the gathering process. In addition, it is noteworthy to mention that some of these data needs are already being fulfilled through certain data collection requirements of the RAWP.

The following subsections provide the qualitative data gap evaluation and data needs identification details for each general design variable. Each subsection discusses the data gaps and data needs for both potential source waters (St. Louis Tunnel Area and Blaine/Argentine Area). Each subsection may be further separated into subsections to identify the data gaps and needs for each retained treatment technology. The following symbols are used in each subsection and in Table 4 to illustrate the status of each data requirement:

● – Filled circles represent completed data requirements.

◑ – Half-filled circles represent partially completed data requirements.

○ – Open circles represent incomplete data requirements

5.2.1 Influent Flow

All Technologies

A Water Quality Assessment conducted by the CDPHE provides preliminary design flow data for a water treatment facility located at the St. Louis Tunnel. This data is based on historical data for average monthly discharges from the pond system and have been adjusted for evaporation and seepage losses. The stated design capacity for the treatment facility in the WQA was based on the maximum recorded discharge of the St. Louis Tunnel.

◑ – This data requirement has been marked as partially complete for the St. Louis Tunnel Area, as additional monitoring and analysis of flow data will be required to adequately characterize the temporal changes in flow rate from the St. Louis Tunnel and to develop appropriate treatment system design criteria. Furthermore, it is important to understand how flows from the St. Louis Tunnel would change if the Source Water Investigation work (RAWP Task E) indicated that independent capture of source water at the Blaine/Argentine area was possible.

Since there is relatively little flow data available from the Blaine/Argentine area, implementation of a treatment system at this location requires further investigation and analysis of flow rates from the Blaine and Argentine mine workings.

○ – This data requirement has been marked as incomplete for the Blaine/Argentine area for all applicable treatment technologies.

5.2.2 Influent Water Chemistry

All Technologies

Historical and current water quality data have been evaluated to identify contaminants and concentrations specific to the St. Louis Tunnel, Blaine, and Argentine sources.

◑ – Per Task A of the RAWP, further sampling and analysis is required for continuing characterization of discharge concentrations. This is especially important for the Blaine/Argentine area, as very little current water quality data is available for this area. This data requirement has been marked as partially complete for all applicable retained technologies for both the St. Louis Tunnel area and the Blaine/Argentine area.

5.2.3 Discharge Standards

All Technologies

Preliminary discharge requirements for the Dolores River, Segment COSJDO03, are defined in the WQA completed in 2008 by the CDPHE. Discharge limits defined in this article are Water Quality Based (WQBELs), Anti-degradation Based (ADBACs), or Non-Impact Limits (NILs). CDPHE will develop the final discharge requirements for the St. Louis Tunnel area if deemed appropriate.

◑ – This data requirement has been marked as partially complete for the St. Louis Tunnel area for all applicable treatment technologies to allow for the development of the final discharge requirements.

For the purpose of evaluating a potential treatment system at the Blaine/Argentine area, a water quality assessment may have to be performed for the possible discharge of treated water into Silver Creek Segments COSJDO05_743D and COSJDO09_743D, which may require significant additional data collection from the Blaine/Argentine source water and Silver Creek.

○ – This data requirement has been marked as incomplete for the Blaine/Argentine area for the applicable treatment technologies.

5.2.4 Performance/Effectiveness

Lime Addition – Lagoon Settling

Previous bench scale testing and lime addition system operation has indicated that lime addition – lagoon settling technology should be effective in meeting discharge standards. For efficient use of available space at the St. Louis Ponds area, further data collection and/or evaluation should be conducted to determine pond volume required for solids removal. Additional lime titrations of collected samples may be required to develop more accurate lime dosing requirements in light of the final discharge standards (when issued). Additional data collection may be required to develop estimates of solids volumes, solids handling characteristics, and solids drying characteristics.

◑ – This data requirement has been marked as partially complete for the St. Louis Tunnel area to allow for the potential collection of additional bench scale test data as deemed necessary.

Lime Addition – HDS Plant

For the St. Louis Tunnel area, laboratory studies have proven lime addition to be an effective means of removing metals from source water upon obtaining pH levels between 9.0 and 9.5. Additional bench scale testing is required to determine particle settling rates, clarifier sizing requirements, solids deposition rates, solids chemical characteristics, and other design criteria.

◑ – This data requirement has been marked as partially complete for the St. Louis Tunnel area to allow for the potential collection of additional bench scale test data as deemed necessary.

For the Blaine/Argentine area, no laboratory testing has been conducted to ensure that the lime addition would be an effective means of removing metals. Additional bench scale testing of Blaine/Argentine area water is required to evaluate effectiveness in meeting discharge standards, anticipated pH target, solids generation rates, particle settling rates, clarifier sizing requirements, solids deposition rates, solids chemical characteristics, and other design criteria.

○ – This data requirement has been marked as incomplete for the Blaine/Argentine area to allow for the potential collection of additional bench scale test data as deemed necessary.

Constructed Wetland

Although the effectiveness of constructed wetlands in meeting discharge requirements under variable flow rates is low, this technology may be sufficient in meeting discharge standards if separate treatment of Blaine and Argentine flows improves water quality conditions at the St. Louis Tunnel. Examination of collected data is required in determining the extent of treatment required by a constructed wetland system. Bench scale and pilot scale testing of constructed wetland technology should be performed to ensure that constructed wetland technology can meet established discharge standards under the anticipated flow conditions. Since the closure of the existing lime addition facility in 1996, the existing pond system has essentially functioned as a free water surface constructed wetland. While the uppermost ponds have accumulated solids from the previous lime addition system and naturally precipitated metals (some of which have been recently moved to dewatering cells), the lower ponds have become sustained wetland environments. Consideration of the constructed wetland technology would benefit from an evaluation of the performance of this existing wetland system while the Blaine/Argentine flows are being separately collected and removed from the flow system, if it is deemed feasible to separately capture and manage source water at the Blaine/Argentine area under RAWP Task ***E***.

◑ – This data requirement has been marked as partially complete for the St. Louis Tunnel area to allow for the continued collection of water quality data and the potential collection of bench scale and/or pilot scale testing data.

Ion Exchange

Since performance of the ion exchange technology can be affected greatly by the influent water chemistry and flow, bench scale and pilot scale testing of this technology is required to evaluate the effectiveness of treating mine discharges at the Blaine/Argentine and St. Louis Tunnel Areas. Such data is necessary to understand resin selection requirements, resin performance and lifespan, potential for resource recovery, capital cost, and operation & maintenance cost.

○ – This data requirement has been marked as incomplete for both the St. Louis Tunnel area and the Blaine/Argentine area to allow for the collection of additional bench and/or pilot test data.

5.2.5 Existing Pond Integrity

All Technologies

The continued utilization of the existing pond system at the Rico-Argentine Mine Site is a valuable option for implementation of many of the retained treatment technologies. Further investigation of long-term function, stability, and safety of the existing pond system is required before including the use of the various ponds in site-specific treatment alternatives. Data needs include embankment soil characteristics and embankment geotechnical stability, both of which are currently in the process of being fulfilled as part of Subtask B3 of the RAWP.

◑ – This data requirement has been marked as partially complete for all technologies.

5.2.6 Solids Management

Lime Addition – Lagoon Settling & Lime Addition – HDS Plant

Consistent with Task B and Task C of the RAWP, various data needs are required to evaluate the solids management options for the lime addition technologies. These data needs include physical and geotechnical properties of the solids; dewatering characteristics of the solids, and anticipated analysis of the volume of solids disposal required. The volume of solids to be managed may be different for each of the lime treatment technologies. Additional data needs may also include the solids settling characteristics and disposal location assumptions. Data is required to develop the design criteria/characteristics of a solids dewatering method and solids repository, which may differ between the two lime treatment technologies.

◑ – This data requirement has been marked as partially complete for both the St. Louis Tunnel area and the Blaine/Argentine area.

Constructed Wetland

For the constructed wetland technology, data gaps were identified related to the potential physical and chemical characterization of the generated solids; volume of solids, and the time interval between solids management (often referred to as wetland lifespan). Data needs may be fulfilled through a combination of literature search and bench/pilot technology testing.

◑ – This data requirement has been marked as partially complete for the St. Louis Tunnel area.

Ion Exchange

For ion exchange technology, the characteristics of the waste stream are a significant data gap. Data needs related to this data gap include the need for bench and/or pilot testing to evaluate waste stream volume and chemical characteristics. Additional analysis can then be conducted to evaluate the potential resource recovery and costs related to O&M (resin regeneration, wastes generated, and waste disposal).

○ – This data requirement has been marked as incomplete for both the St. Louis Tunnel area and Blaine/Argentine area.

6.0 Report Summary

In accordance with Subtask FI of the RAWP, this report has provided a technology screening for water treatment of discharges from the Rico-Argentine Mine Site. Technologies were researched and then screened based upon effectiveness, implementability, and cost criteria. Those retained for the further assemblage of site-specific treatment alternatives are as follows:

1. Lime Addition – Lagoon Settling;
2. Lime Addition – High Density Sludge Plant;
3. Constructed Wetlands; and
4. Ion Exchange.

In addition to the screening of technologies, this report has conducted an evaluation of data gaps and identification of data needs for the various technologies. This exercise has resulted in the development of various data needs for each treatment technology that may require additional data collection and/or assessment in order to provide a systematic and thorough evaluation of site-specific treatment alternatives. The identified data gaps are illustrated in **Table 4: Water Treatment Technology Screening Data Gap Evaluation**. The identified data needs are shown in **Table 5: Water Treatment Technology Screening Data Needs Identification**, and are summarized as follows:

1. Data needs for Lime Addition – Lagoon Settling technology;
   a. Additional St. Louis Tunnel water quality and flow data
   b. Historical lime treatment data
   c. Final discharge requirements
   d. Bench test data
   e. Water balance and residence time for existing pond system
   f. Hydrologic data for the evaluation of existing pond system integrity
   g. Geotechnical data for the evaluation of existing pond embankment stability
   h. Solids data: volumes generated, disposal location assumptions, and physical, chemical, dewatering, and settling characteristics

2. Data needs for Lime Addition – High Density Sludge plant technology;
   a. Additional St. Louis Tunnel water quality and flow data
   b. Water quality and flow data for the Blaine and Argentine sources
   c. Final discharge requirements
   d. If discharge is anticipated to Silver Creek, then additional data is required to develop Silver Creek discharge standards
   e. Bench test data for clarifier performance and sizing
   f. Bench test data to evaluate solids management requirements
   g. Pilot testing for treatment and solids management requirements
   h. Hydrologic data for the evaluation of existing pond system integrity
   i. Geotechnical data for the evaluation of existing pond embankment stability
   j. Solids data: volumes generated, disposal location assumptions, and physical, chemical, dewatering, and settling characteristics

3. Data needs for Constructed Wetlands technology; and
    a. Changes to St. Louis Tunnel water quality if it is assumed Blaine/Argentine source is captured and removed
    b. Final discharge requirements
    c. Bench testing
    d. Pilot testing
    e. Hydrologic data for the evaluation of existing pond system integrity
    f. Geotechnical data for the evaluation of existing pond embankment stability
    g. Solids data: volumes generated, cleanout requirements, and physical and chemical characteristics

4. Data needs for Ion exchange technology.
    a. Additional St. Louis Tunnel water quality and flow data
    b. Water quality and flow data for the Blaine and Argentine Sources
    c. Final discharge requirements
    d. If discharge is anticipated to Silver Creek, then additional data is required to develop discharge standards for Silver Creek
    e. Bench test data (determine regeneration requirements and life expectancy of resin)
    f. Pilot test data
    g. Water balance and residence time for existing pond system
    h. Hydrologic data for the evaluation of existing pond system integrity
    i. Geotechnical data for the evaluation of existing pond embankment stability
    j. Solids/Waste Stream data: volume generated, and physical and chemical characteristics
    k. Evaluations for potential resource recovery from waste stream

The screening of treatment technologies has resulted in four treatment technologies that may be effective, impiementable, and cost effective for the treatment of the various source waters at the Rico-Argentine Mine Site. However, significant data gaps were identified that will limit the ability to accurately and systematically evaluate site-specific treatment alternatives. Collection of additional data (some of which is currently underway as part of the RAWP activities), will fill the data gaps and allow for the development of more detailed and comparable site-specific treatment alternatives, which will be the next step in the Water Treatment System Analysis and Design Task of the RAWP. To streamline the amount of data potentially required to fulfill the data needs, a prioritization of data needs will be conducted in order to rank the importance/urgency of the data collection and evaluation activities. This prioritization may reduce the need for subsequent data collection activities if the collected data can be used to further screen the most promising retained technologies or site-specific treatment alternatives.

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Tables

Table 1: Influent Water Quality & Flow Rate

	St. Louis Tunnel[1] (ug/L)				Blaine Adit[2] (ug/L)				Argentine Shaft[3] (ug/L)	
Parameter[5]	n	Avg	Max	Min	n	Avg	Max	Min	n	Value
As, Trec	3	1.85	2.1	1.7	-	-	-	-	-	-
Cd, Dis	25	26.3	80.4	10	4	2,320	7,000	26.7	1	246
Cr, Dis	2	0.3	0.6	0	1	32.4	32.4	32.4	1	14.3
Cr, Trec	10	1.4	9.8	0	1	1.4	1.4	1.4	-	-
Cu, Dis	24	35	217	0	4	15,081	50,000	413	1	2,640
CN, Free	6	0.003	0.011	ND	1	ND	ND	ND	1	ND
Fe, Trec	14	8,800	16,100	3,200	1	14,200	14,200	14,200	-	-
Pb, Dis	21	6.3	100	0	4	196	505	48	1	225
Mn, Dis	27	2,498	4,320	1,700	4	73,273	149,000	1,090	1	20,600
Ni, Dis	15	4.8	19.8	0	1	84	84	84	1	63.8
Se, Dis	11	0.01	0.1	0	2	2.9	3.6	2.2	1	2.4
Ag, Dis	19	0.02	0.18	0	4	0.74	1.5	ND	1	0.52
Zn, Dis	28	4,500	13,900	1,400	4	19,3320	489,000	3,280	1	47,800
Flow (gpm)	61	790	2,200[4]	330	31	2.12	15	.75	-	-
pH	17	6.7	7.2	6.3	37	2.96	7.4	1.8	1	3.5

Table Notes:

1. St. Louis Tunnel concentrations and flow rate are based on data from 9/1973 to 6/2011.
2. Blaine Adit concentrations and flow rate are based on data from 9/1977 to 8/2011.
3. Argentine Adit concentrations are based on data from 8/2011.
4. The maximum flow was determined using the maximum recorded discharge of the St. Louis Tunnel.
5. Parameter list based upon those shown in Table A-17 of the CDPHE, 2008 Water Quality Assessment
6. Abbreviations: n = # of Samples, Trec = Total Recoverable, Dis = Dissolved, ND = Not Detected

Table 2: Preliminary Discharge Limits to the Dolores River

Parameter	WQBEL[2] (ug/L)	ADBAC[2] (ug/L)	NIL[2] (ug/L)
As, Trec	21	3.7	0
Cd, Dis	2.3	N/A	80.1
Cr (VI), Dis	31.1	4.6	0
Cr (III), Trec	285	44	1.6
Cu, Dis	51.1	8.1	15.7
CN, Free	9.8	1.5	0
Fe, Trec	2,719	903	1,410
Pb, Dis	18.4	3.0	1.22
Mn, Dis	6,289	1,908	4,210
Ni, Dis	319	48	10
Se, Dis	11.8	2.9	1.39
Ag, Dis	4.2	0.58	0.27
Zn, Dis	729	476	13,500

Table Notes:

1. Source: CDPHE, 2008. Water Quality Assessment: Mainstem of the Dolores River, St. Louis Tunnel Discharge.
2. WQBEL = Water Quality Based Effluent Limit, ADBAC = Antidegradation Based Average Concentration, NIL = Non-Impact Limits
3. ADBACs and NILs are not applicable when the WQBELs are less than the NILs, or when the WQBELs are less than the ADBACs. For cadmium and zinc the NIL is greater than the WQBEL, therefore, the ADBACs and NILs do not apply. For the pollutants for which ADBACs and NILs apply, the permit holder can choose between the two alternatives based on which appears easier to comply with.

Abbreviations: Trec = Total Recoverable Dis = Dissolved

Table 3: Water Treatment Technology Screening

Remedial Technology	Effectiveness[1]		Implementability[2]			Costs[3]			Screening Status	Comments
	Removal Efficiency / Immobilization[1a]	Capability to Meet Aquatic & Human Health Standards[1b]	State of Technical Development[2a]	Residuals/Emissions Generated[2b]	Management Considerations[2c]	Capital[3a]	Operations and Maintenance[3b]	Resource Recovery Potential[3c]		
Biological Treatment										
Microbial Mats	Moderate	Low	Pilot/Innovative	Exhausted Mats	Maintenance & Monitoring, Eventual need to replace microbial mat	Low	Low to Moderate	Maybe	Not Retained	Low cost system typically used for temporary applications. Semi-passive technology with low energy and maintenance requirements. Decreases mass of waste disposal and has potential for metal recovery. Not an effective treatment for high concentrations of Fe, Mn, Al, or low pH water or higher flow rates. Suspended solids in the wastewater need to be removed prior to treatment. Trace metal toxicity may inhibit microbial viability. Optimum system performance requires hot climates with abundant sunshine. Most commonly used in conjunction with other treatment systems. Not retained. Innovative technology with low probability of meeting effluent requirements when used as a standalone process.
Sulfate Reducing Bioreactor	Low to High	Low to Moderate	Pilot/Innovative	Sediment & Sludge	Maintenance & Monitoring, Eventual need to replace reactor media	Low to Moderate	Moderate	Maybe	Not Retained	Most bioreactors can only accommodate low flow rates. Some systems can be designed to generate sulfide separately from the precipitation chamber/pond. Flow rates, retention time, chemical addition, and pumping must be regulated for optimum performance. Reactors can be constructed in remote areas; though may require significant maintenance. Organics, nutrients, hydrogen sulfide gas, and/or certain metals may be released from the bioreactor. Variable flow rates, climate, clogging, and influent chemistry can disrupt performance. Long-term, full-scale performance data for case studies is limited. Requires a large footprint. Operation and maintenance costs could be substantial due to routine adjustment of multiple control factors. Not retained due to associated high costs, health risks, and low effectiveness under high flow conditions.
Constructed Wetland	Low to Moderate	Low to Moderate	Pilot/Innovative	Sediment & Sludge	Maintenance & Monitoring, Eventual need to replace wetland media	Low to Moderate	Low to Moderate	No	Retained	Passive technology designed to require little energy input. Decreased air emissions. May be applicable in remote locations, or where consistent compliance with standards is not required. May also provide wildlife habitat creation. Has been used as a method to create carbon dioxide and greenhouse gas sequestration. Variable flow rates and influent chemistry can disrupt performance. Climate may adversely affect treatment. A large area is required for construction. Clogging and preferential flow have been illustrated in many systems. Long term, full scale performance data is limited. Retained due to low capital and O&M costs associated with implementing this technology on-site. May be sufficient in meeting discharge standards if separate treatment of Blaine and Argentine flows improves water quality conditions at the St. Louis Tunnel.
Chemical Treatment										
Anoxic Limestone Drain	Low to Moderate	Low	Conventional	Sludge	Monitoring, Eventual need to replace limestone drain	Low	Low	No	Not Retained	Low cost, passive system that is easy to construct. Technology yields immediate results and covers a wide range of climate variances. Limited long-term reliability and range of geochemical conditions. Low probability of consistently meeting low effluent standards. Not Retained. Variable life span. Inconsistent removal efficiencies under variable flow conditions.
Electrocoagulation	Moderate	Moderate	Pilot/Innovative	Sludge	Maintenance & Monitoring, Electrode Replacement	High	High	Maybe	Not Retained	Requires simple equipment and is easy to operate. Treated water is palatable, clear, colorless, and odorless. Sludge is easily separated and easy to dewater. Technology is unproven and requires high operation and maintenance costs. Regular replacement of electrodes is required. Typically used only for polishing or pre-treatment. Not Retained. Likely not applicable to source water conditions and flow range, unless as pretreatment for other process technology.
Ion Exchange	Moderate to High	Moderate to High	Conventional	Exhausted Resins	Maintenance & Monitoring, Potential for fouling of resin and need for replacement	High	Moderate to High	Maybe	Retained	Technology yields immediate results for temporary or permanent applications. May meet low-level discharge permit requirements for certain constituents. Not an effective treatment for high concentrations of Fe, Mn, Al, or low pH water. Case Study suggests copper may not be consistently removed to aquatic discharge standards. Not effective for complex mixtures of metals. Suspended solids need to be removed prior to treatment and requires ongoing operational costs. Resin can become fouled. Retained for potential use in treatment of Blaine source water.

Table 3: Water Treatment Technology Screening

Remedial Technology	Effectiveness[1]		Implementability[2]			Costs[3]			Screening Status	Comments
	Removal Efficiency / Immobilization[1a]	Capability to Meet Aquatic & Human Health Standards[1b]	State of Technical Development[2a]	Residuals/Emissions Generated[2b]	Management Considerations[2c]	Capital[3a]	Operations and Maintenance[3b]	Resource Recovery Potential[3c]		
Lime Treatment – Lagoon Settling	High	High	Conventional	Sludge	Maintenance & Monitoring	Moderate	Low to High	No	Retained	Typically lower capital construction cost in comparison to mechanical clarification precipitation systems. Proven lime precipitation technology. Able to meet stringent discharge standards. Able to handle large flow variability. Limited control of system. Lower removal efficiency can be expected with high flow rates. A large area is required for construction. Variable costs for solids removal depending upon quality of sludge and dewatering method. Relative to other lime treatment technologies, operation and maintenance costs can be low due to less labor and maintenance of mechanical systems, and if sludge can be managed locally. Retained. Proven technology with consistent removal efficiency.
Lime Treatment – Conventional Plant	High	High	Conventional	Sludge	Maintenance & Monitoring	Moderate to High	Moderate to High	No	Not Retained	Well proven and accepted technology in the industry with relatively simple operation and low cost of chemical addition. May not be effective, or may require multiple stages if dissolved metals require a wide pH range for removal. Sludge quantities can be substantial, be difficult to dewater, and require extensive costs due to continuous sludge management. Hydroxide precipitates tend to dissolve back into solution if the pH is lowered. Not retained. Technology may be upgraded to an HDS process with minimal capital investment. These processes yield solid wastes with better manageable qualities.
Lime Treatment –High Density Sludge Plant	High	High	Conventional	Sludge	Maintenance & Monitoring	Moderate to High	Moderate to High	No	Retained	Well proven and accepted technology in the industry with relatively simple operation and low cost of chemical addition. Ease of automatic pH control. Increased efficiency of lime usage in comparison to non-HDS lime treatment systems. Sludge generated can be >30% solids. May not be effective, or may require multiple stages if dissolved metals require a wide pH range for removal. Sludge quantities can be substantial. Little metal hydroxide precipitation occurs at ph<6. Hydroxide precipitates tend to dissolve back into solution if the pH is lowered. Though less sludge is generated than other lime treatment approaches, sludge management costs can be substantial due to continuous disposal efforts. Retained. Proven and reliable technology.
Chemical Sulfide Precipitation	High	Moderate	Conventional	Sludge	Maintenance & Monitoring	Moderate to High	High	Maybe	Not Retained	May attain a high degree of metal removal, even with low pH values. Low detention time requirements in the reactor due to the high reaction rates of sulfides. Selective metal removal and recovery is feasible. Metal-Sulfide sludge theoretically exhibits better thickening and dewatering characteristics. Metal-sulfide sludge is less subject to leaching at lower pH levels. Potential for toxic hydrogen sulfide gas emissions. Potential for residual sulfide in treatment effluent. Soluble sulfide process may result in an odor problem or potential safety issues with H2S gas generation. Higher capital and operating costs than hydroxide precipitation. Process can be relatively complex and requires precise process control which may be difficult to maintain. Metal sulfide sludge is subject to oxidation in the presence of oxygen and water. Not effective in significantly reducing manganese concentrations. Residual sulfide may remain in effluent. Not Retained. Relatively high cost and potential safety and odor issues.
Physical Treatment										
Electrodialysis	High	High	Conventional	Brine	Maintenance & Monitoring; potential fouling of resin plates	High	High	Maybe	Not Retained	Typically used in desalination facilities. Can achieve high water quality requirements. Technology requires high operation and maintenance costs. Resin membrane plates subject to potential fouling by organics, biological products, or suspended solids. Requires a very low turbidity influent (though more tolerant than RO technology) Non-charged, high molecular weight species will not be significantly removed. Less economical when treating solutions with low salt concentrations. Not retained. High cost and potential for fouling due to suspended particulates.
Evaporation Ponds	Low	N/A	Conventional	Sediment	Maintenance & Monitoring	Low	Low	No	Not Retained	Low operation and maintenance costs. Easily constructed and implemented technology. Large footprint required. Long-term data shows potential contaminant releases under high flow conditions. Not Retained. Not possible to meet discharge requirements unless combined with other technology.
Reverse Osmosis	High	High	Conventional	Brine	Maintenance & Monitoring, Potential for Membrane fouling / replacement	High	Very High	No	Not Retained	Long-term effectiveness. Large range of solute rejection. Tested technology and flexible application with relatively small footprint. Attainment of stringent regulatory standards. High capital and very high O&M costs. Requirement of osmotic pressure. Fouling of membranes and potential scaling problems. Reliance on external power. Very intolerant of influent suspended solids, thus would likely require influent pretreatment. Potential difficulty of concentrate disposal. Not Retained due to high costs and influent characteristics.

Table 3: Water Treatment Technology Screening

Table Notes:

1. Effectiveness criteria were selected for the purpose of screening technologies based upon level of contaminant reduction and ability to meet applicable standards.
    a. Removal Efficiency/Immobilization: Table value describes the ability of the technology to reduce contaminant concentrations relative to the influent concentration.
        - Low – Relatively little reduction in contaminant concentrations.
        - Moderate – Moderate reduction in contaminant concentrations.
        - High – High level of reduction of contaminant concentrations.
    b. Capability to Meet Aquatic and Human Health Standards: Table value describes the ability of technology to meet anticipated discharge compliance limits.
        - Low – Technology is not likely to achieve treatment performance standard.
        - Moderate – Technology may achieve treatment performance standard.
        - High – Technology is likely to achieve treatment performance standard.

2. Implementability criteria were selected for the purpose of screening technologies based upon the proven or uncertain nature of the technology and other implementability considerations such as waste product generated. Technology performance data, resources required, and site specifics were evaluated in evaluating technology implementability.
    a. State of Technical Development: Table value describes the technology's state of development for implementation on a long-term, full-scale basis
        - Conventional – Proven, reliable technology in treating water associated with mining operations. Long-term, full-scale data is available of technology's effectiveness.
        - Pilot/Innovative – Limited data is available on the technology's reliability to treat water associated with mining operations in long-term, full-scale circumstances.
    b. Residuals/Emissions Generated: Table value describes a general category of the waste product(s) created in the water treatment process that require management and/or disposal.
        - Brine – Solute byproduct resulting from treatment process.
        - Sludge – Water and precipitate byproduct resulting from treatment process.
        - Sediment – Miscellaneous solids accumulated as a waste product in treatment process.
    c. Management Considerations: Table value describes the miscellaneous implementability considerations for each technology.
        - Maintenance – Some level of maintenance is required to preserve the integrity of the treatment process.
        - Monitoring – Monitoring is required to ensure performance of treatment technology.

3. Cost criteria were selected for the purpose of screening technologies on the basis of capital cost, operation and maintenance cost, and resource recovery potential.
    a. Capital Costs: Table value describes the anticipated cost associated with construction of the treatment system.
        - Low – Technology is associated with a low cost of construction.
        - Moderate – Technology is associated with an average cost of construction
        - High – Technology is associated with a high cost of construction.
    b. Operating and Maintenance Costs: Table value describes the anticipated ongoing cost associated with monitoring and maintaining the treatment system.
        - Low – Technology is associated with low annual costs.
        - Moderate – Technology is associated with average annual costs.
        - High – Technology is associated with high annual costs.
    c. Resource Recovery Potential: Table value describes the potential for recovering byproducts from solution that may be sold to offset treatment costs.
        - Yes – Technology is conducive to economically recovering byproducts for sale.
        - No – Technology is not conducive to economically recovering byproducts for sale.

Table 4: Water Treatment Technology Screening Data Gap Evaluation

Design Variable	Technology							
	Lime Addition – Lagoon Settling		Lime Addition – HDS Plant		Constructed Wetland		Ion Exchange	
	St. Louis Tunnel Area	Blaine/Argentine Area	St. Louis Tunnel Area	Blaine/Argentine Area	St. Louis Tunnel Area	Blaine/Argentine Area	St. Louis Tunnel Area	Blaine/Argentine Area
Influent Flow	◑	N/A	◑	○	◑	N/A	◑	○
Influent Water Chemistry	◑	N/A	◑	◑	◑	N/A	◑	◑
Discharge Standards	◑	N/A	◑	○	◑	N/A	◑	○
Performance /Effectiveness	◑	N/A	◑	○	◑	N/A	○	○
Existing Ponds Integrity	◑	N/A	◑	N/A	◑	N/A	◑	N/A
Solids Management	◑	N/A	◑	◑	◑	N/A	○	○

Table Notes:

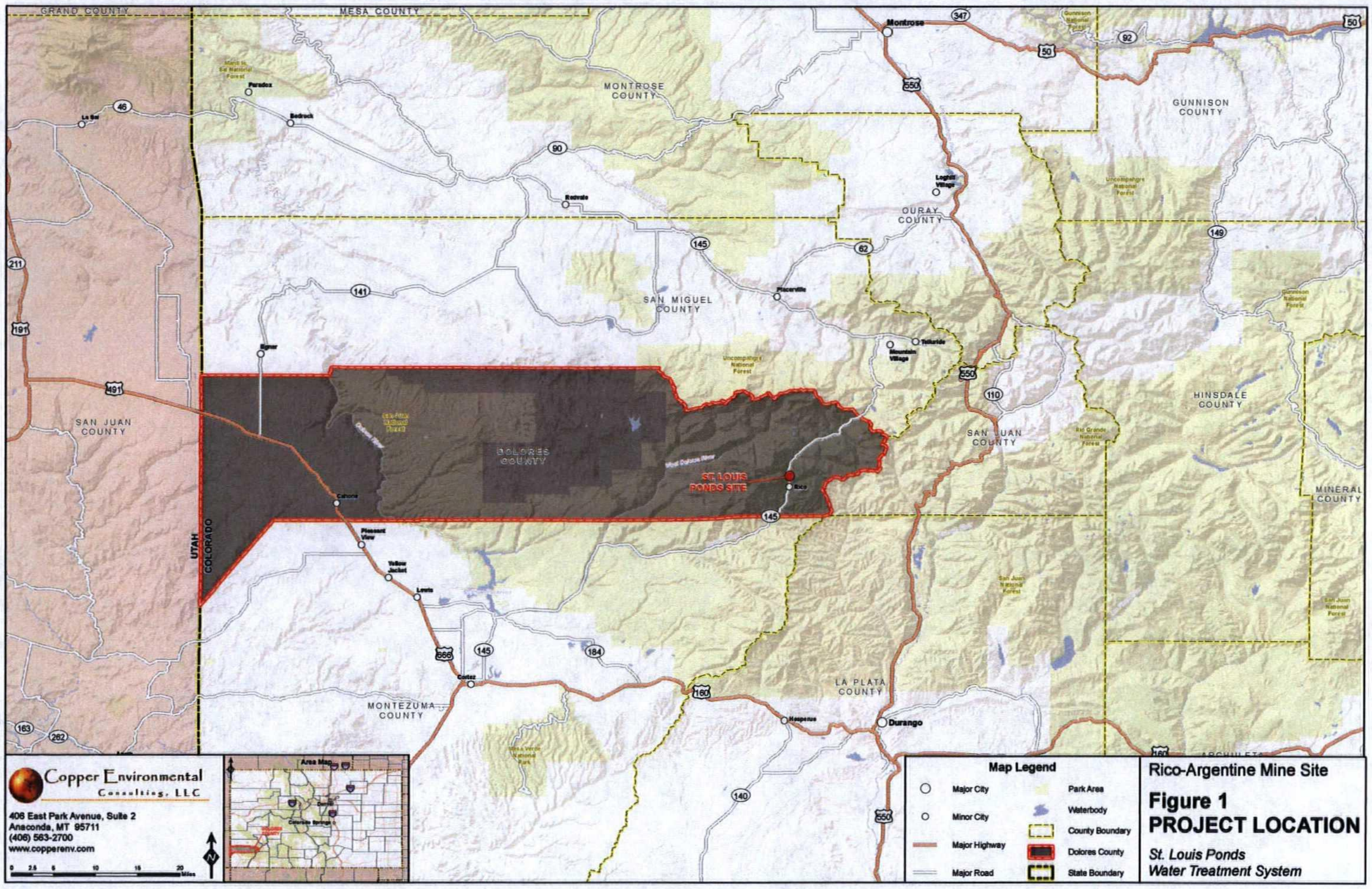
● – Data requirement complete. ◑ – Data requirement partially complete. ○ – Data requirement incomplete.

Table 5: Water Treatment Technology Screening Data Needs Identification

Design Variable	Technology							
	Lime Addition – Lagoon Settling		Lime Addition – HDS Plant		Constructed Wetland		Ion Exchange	
	St. Louis Tunnel Area	Blaine/Argentine Area	St. Louis Tunnel Area	Blaine/Argentine Area	St. Louis Tunnel Area	Blaine/Argentine Area	St. Louis Tunnel Area	Blaine/Argentine Area
Influent Flow	o Additional St. Louis Tunnel flow data o Change in flow if separate capture implemented for Blaine/Argentine Area	N/A	o Additional St. Louis Tunnel flow data o Change in flow if separate capture implemented for Blaine/Argentine Area	o Flow measurements of Blaine/Argentine sources	o Additional St. Louis Tunnel flow data o Change in flow if separate capture implemented for Blaine/Argentine Area	N/A	o Additional St. Louis Tunnel flow data o Change in flow if separate capture implemented for Blaine/Argentine Area	o Flow measurements of Blaine/Argentine sources
Influent Water Chemistry	o Additional St. Louis Tunnel water quality data o Historical lime treatment data	N/A	o Additional St. Louis Tunnel water quality data	o Water quality of Blaine/Argentine Sources	o Changes to St. Louis tunnel water quality if it is assumed Blaine/Argentine source is captured and removed	N/A	o Additional St. Louis Tunnel water quality data	o Water quality of Blaine/Argentine Sources
Discharge Standards	o Final discharge requirements	N/A	o Final discharge requirements	o If discharge is anticipated to Silver Creek, then additional data required to develop discharge standards	o Final discharge requirements	N/A	o Final discharge requirements	o If discharge is anticipated to Silver Creek, then additional data required to develop discharge standards
Performance /Effectiveness	o Bench Test o Historical lime treatment data o Water balance and residence time of existing pond system	N/A	o Bench tests needed for clarifier performance evaluation o Bench tests to evaluate solids management requirements	o Bench tests needed for clarifier performance evaluation discharge standards o Bench tests to evaluate solids management requirements o Pilot testing	o Bench tests o Pilot tests	N/A	o Bench tests o Pilot tests o Water balance and residence time of existing pond system	o Bench tests o Pilot tests
Existing Ponds Integrity	o Hydrologic data o Geotechnical data	N/A	o Hydrologic data o Geotechnical data	N/A	o Hydrologic data o Geotechnical data	N/A	o Hydrologic data o Geotechnical data	N/A
Solids Management	o Solids volume o Solids physical and chemical characteristics o Solids dewatering characteristics o Solids settling characteristics o Disposal location assumptions	N/A	o Solids volume o Solids physical and chemical characteristics o Solids dewatering characteristics o Solids settling characteristics o Disposal location assumptions	o Solids volume o Solids physical and chemical characteristics o Solids dewatering characteristics o Solids settling characteristics o Disposal location assumptions	o Solids volume generated o Solids physical and chemical characteristics o Solids cleanout requirements	N/A	o Volume of waste generated o Physical and chemical characteristics of waste o Potential for resource recovery from waste	o Volume of waste generated o Physical and chemical characteristics of waste o Potential for resource recovery from waste

Table Notes:
1. N/A – Not Applicable.

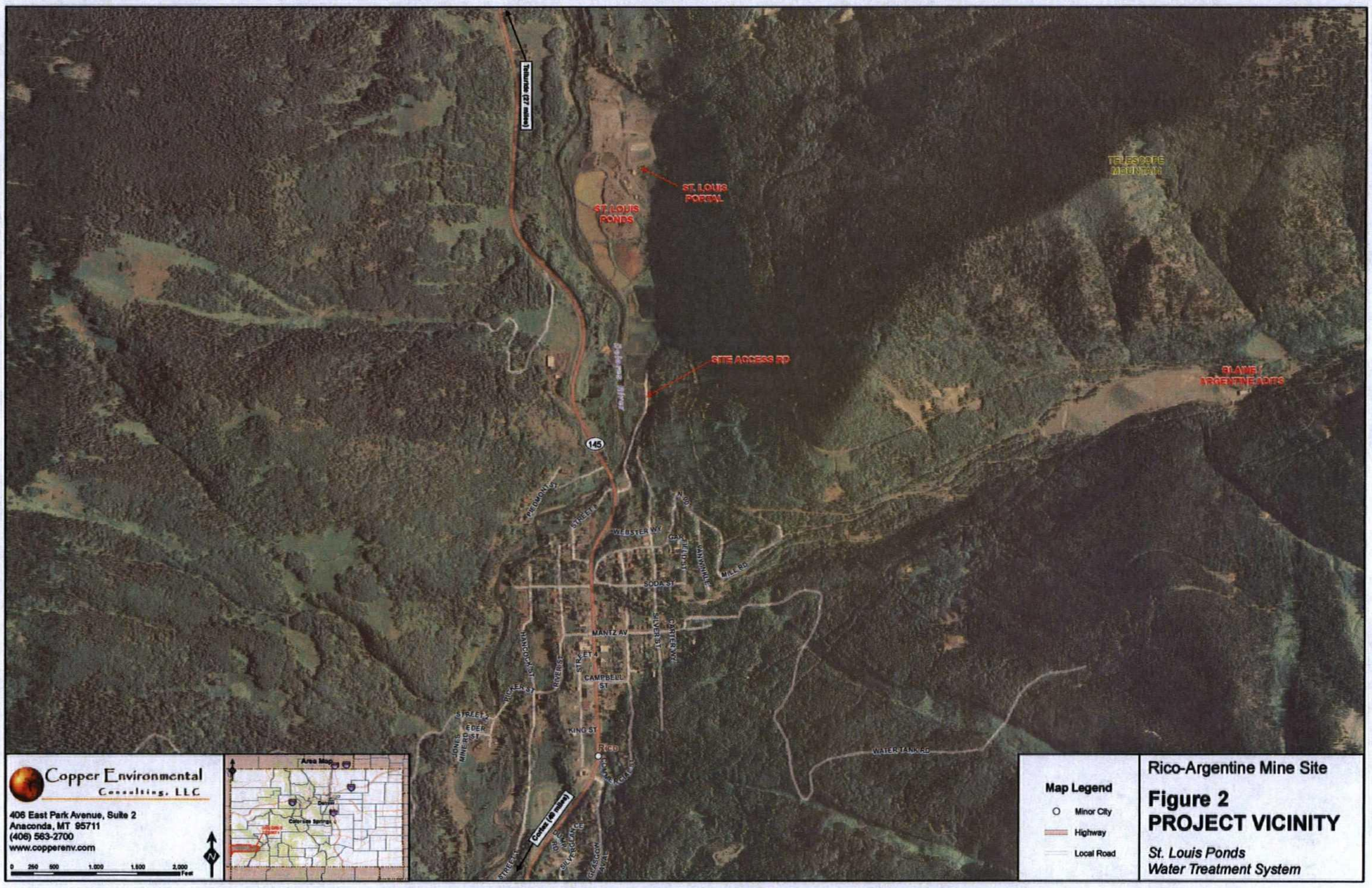
Figures



Rico-Argentine Mine Site

Figure 1
PROJECT LOCATION

St. Louis Ponds
Water Treatment System



Rico-Argentine Mine Site

Figure 2
PROJECT VICINITY

St. Louis Ponds
Water Treatment System